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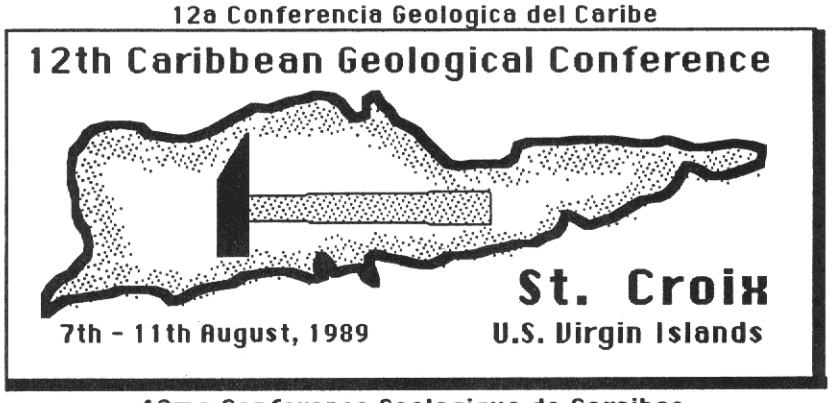

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A NOTE OF THE RELATIVE TIMING OF CLEAVAGE FORMATION AND MAGMATISM IN THE CRETACEOUS ROCKS OF ST. CROIX, U.S. VIRGIN ISLANDS

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ABSTRACT

The Cretaceous sedimentary rocks of St. Croix are characterized by a pervasive slaty cleavage. The timing of the development of this cleavage relative to the emplacement of various major and minor igneous plutons was previously regarded as uncertain, but generally was considered to have taken place before the intrusions. We report the presence in the East End of St. Croix of cleavage in a pyroxene porphyry sill and a diatreme dike. These features indicate at least some of the magmatic activity on St. Croix preceded the cleavage forming deformation. We further suggest that folded quartz veins in the West End of St. Croix, that were involved in the later stages of cleavage formation, may have been derived from cooling igneous bodies at depth. These observations indicate that at least some magmatic activity pre-dated or was approximately synchronous with cleavage formation. If the observed igneous bodies were formed in the same interval as other minor intrusions, this implies that the cleavage formed during or post Maastrichtian - early Paleocene time.

INTRODUCTION

The island of St. Croix is the peak of the St. Croix platform which forms a submarine ridge in the southeastern Greater Antilles. The island is composed of deformed, Upper Cretaceous sedimentary rocks and igneous intrusions (Whetten, 1966; Lidz, 1988; Speed and Joyce, 1989; see also Fig. 1), except for a central graben (Whetten, 1966), or half graben (Speed and Joyce, 1989), which is occupied by limestones of Miocene and younger age.

Whetten (1966) considered the Cretaceous sedimentary rocks to be composed of four stratigraphic units: the Caledonia, Allendale, Cane Valley and Judith Fancy Formations. In contrast, Speed and Joyce (1989) were of the opinion that no coherent stratigraphy can be established and that the Cretaceous rocks are composed of six structural packages, or nappes, labeled K1 through K6 (Fig 1). The Caledonia Formation (nappes K1, K2, K3, K6 of Speed and Joyce, 1989) are composed of turbidites and contourites (Speed, 1974; Speed and Joyce, 1989; Stanley, 1989) containing detrital carbonate, quartz and feldspar grains, with minor chert and debris flow beds. The Allandale, Cane Valley and, in particular, the Judith Fancy (K4, K5) are composed of volcanogenic (?tuffaceous) sandstones and siltstones.

Structurally, the most obvious feature of these rocks a penetrative slaty cleavage (Fig. 2) that is pervasive throughout all units except the Judith Fancy Formation where it is only locally developed in fine grained lithologies (Speed and Joyce, 1989, and authors' own observations). Speed and others (1979) and Speed and Joyce (1989) assert that this structure was formed before the intrusion of major and minor igneous bodies. Hornblende K-Ar dates obtained from minor intrusions (referred to as "dikes" in Speed and Joyce, 1989, but many are sills) range from 71.8 to 66.1 Ma (Speed and others, 1979), but igneous clasts in a pebbly sandstone at Robin Bay yield and age of 75.2 Ma. The sills and dikes are presumed undeformed, and hence the conclusion of Speed and others (1979) and Speed and Joyce (1989) is that the tectonite fabric of the sedimentary rocks took place between 75.2 and 71.8 Ma.

In this note, we describe occurrences of intrusive igneous bodies that either possess a cleavage or were deformed in the later stages of cleavage formation. These observations imply that least some magmatic activity pre-dates or is synchronous with tectonism, and therefore, that cleavage formation in St Croix may have been later than previously suggested.

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CLEAVAGE IN CRETACEOUS SEDIMENTARY ROCKS

Our observations indicate the Cretaceous sediments consist of mainly of impure, arkosic calcarenites with minor quartz clasts, with lesser amounts of calcareous arkoses and graywackes. Beds of chert are present in the East End of St. Croix (Speed and Joyce's K2 nappe), as are arkosic grits (within Speed and Joyce's K3 nappe; Whetten's Grass Point Member).

In outcrop and hand specimen, the cleavage in the sedimentary rocks appears as a planar penetrative fabric, usually at a high angle to bedding (Fig. 2). Our preliminary examination indicate that the cleavage in the rocks of the Caledonia Formation results from several fabric elements:

1) alignment of ellipsoidal carbonate grains (formed form originally equant detrital grains)
2) pressure solution seams, usually anastamosing, of finite length which varies in length from "short" (one to two grain diameters) to "long" (many grain diameters). These are comparable to varieties of "disjunctive" or "wispy" seams of Borradaile and others (1982, p.34).
3) alignment of phyllosilicate grains, some of which are distributed throughout the rock, others of which are concentrated as lenticular pods.

The degree of development of these features are a function of finite strain and mineralogical composition. In general, quartz and feldspar grains are not deformed internally.

SILL LOCATED WEST OF COTTONGARDEN BAY

A sill of andesitic pyroxene porphyry occurs in outcrops on a wave cut platform west of

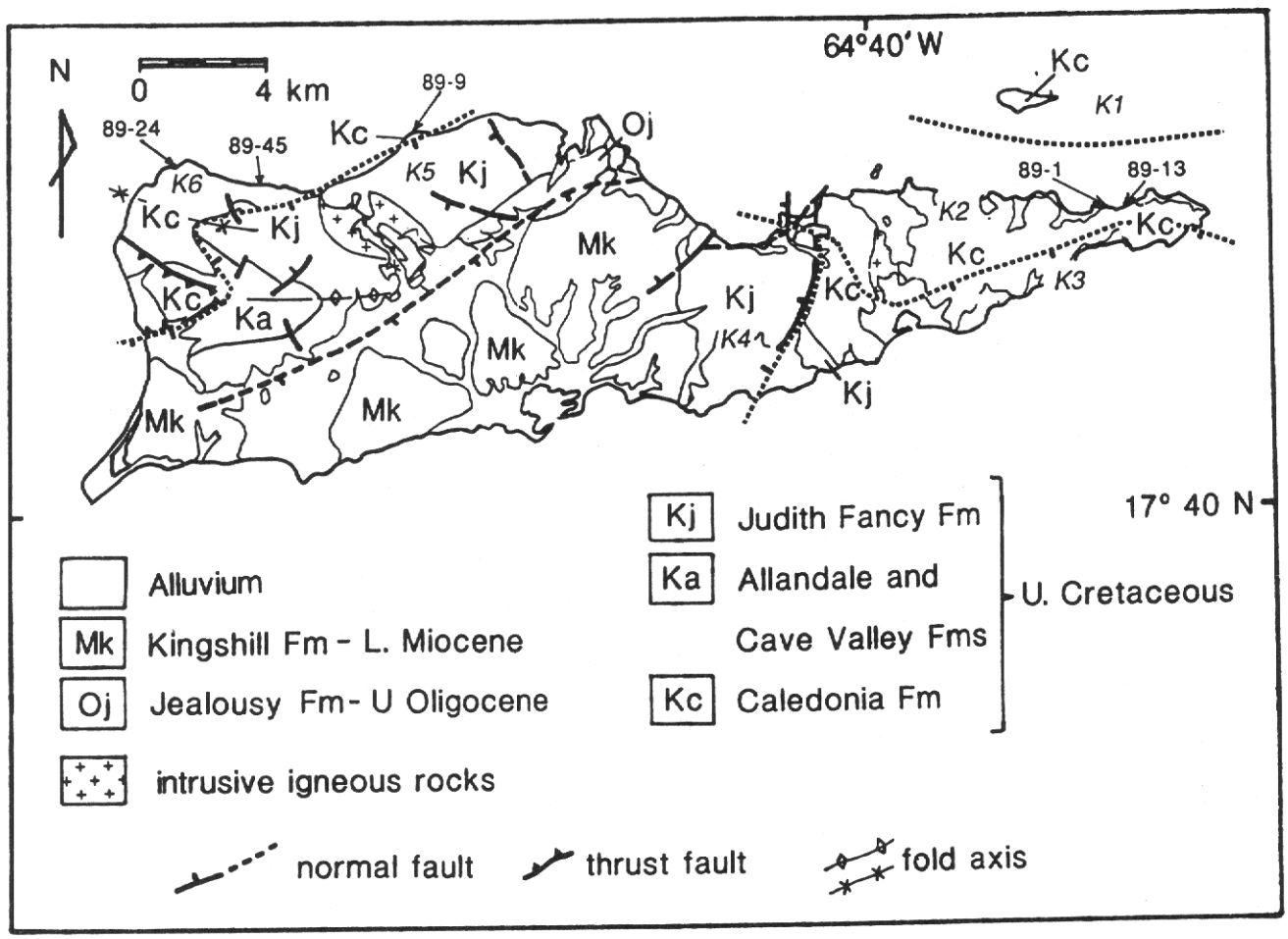

Fig. 1 Geologic map of St. Croix based on Whetten (1966). Boundaries of the nappes of Speed and Joyce (1989) are shown by the dotted lines and labeled in italics. Localities referred to in text are: 89-1 Knight Bay, 89-13 West of Cottongarden Bay, 89-24 Hamm's Bluff, 89-45 west of Annaly Bay.

Cottongarden Bay (grid reference 313642). The 28-30 cm. thick sill occurs in intercalated beds of sandstone, siltstone and chert which strike 108^0 and dip 79^0N . Slaty cleavage in the surrounding sedimentary rocks strikes 004^0 and dips $38\text{-}40^0$E. Cleavage in the sill, which is sub-parallel to the cleavage in the country rock, can easily be observed in the outcrop in the intertidal zone, but is hard to perceive in the more weathered rock exposed in the cliff face.

In thin section, the cleavage is developed as a series of lenticular 2-3mm by 0.4 mm domains of sinuous, anastamosing seams of fine-grained phyllosilicates irregularly distributed throughout the rock.

DIATREME DIKE AT KNIGHT BAY

A small diatreme (explosively emplaced breccia) dike can be observed cutting black siltstones on the east side of Knight Bay (grid reference 312640). The dike has irregular boundaries and is variable in thickness from 30 to 100 cm. Angular clasts in the dike are composed of both volcanic and sedimentary rocks which are up to 10 cm in diameter. The larger volcanic clasts consist of leucocratic, seriate textured dacite and quartz microphenocryst bearing rhyolite. Neither of these igneous lithologies have previously been reported from St. Croix. Devitrified glass shards are found as small (>3mm) clasts in the dike and their presence confirms the interpretation that this body represents an igneous rather than sedimentary intrusion (Speed, personal commuinication).

Mesososcopic scale clasts in the diatreme are deformed into approxomately ellipsoidal shapes with their short axes perpendicular to cleavage planes. Cleavage is developed in the both the sedimentary clasts and the matrix of the diatreme, and has the same orientation in each of these, indicating that cleavage formed after emplacement of the diatreme. The cleavage morphology and architecture in the sedimentary clasts of the dike are identical to those found in the surrounding sedimentary rocks of the Caledonia Formation in that they are defined by (a) preferred orientation of ellipsoidal carbonate grains, (b) phyllosilicate aggregates and (c) anastamosing pressure solution seams. The fabric of the matrix is defined by anastamosing, discontinous pressure solution seams, concentrated on the boundaries of undeformed feldspar and quartz grains, and oriented aggregates and isolated grains of a brown pleochroic phyllosilicate (?stilpnomelane). With the exception of the devitrified glass shards, the igneous clasts have not developed a cleavage.

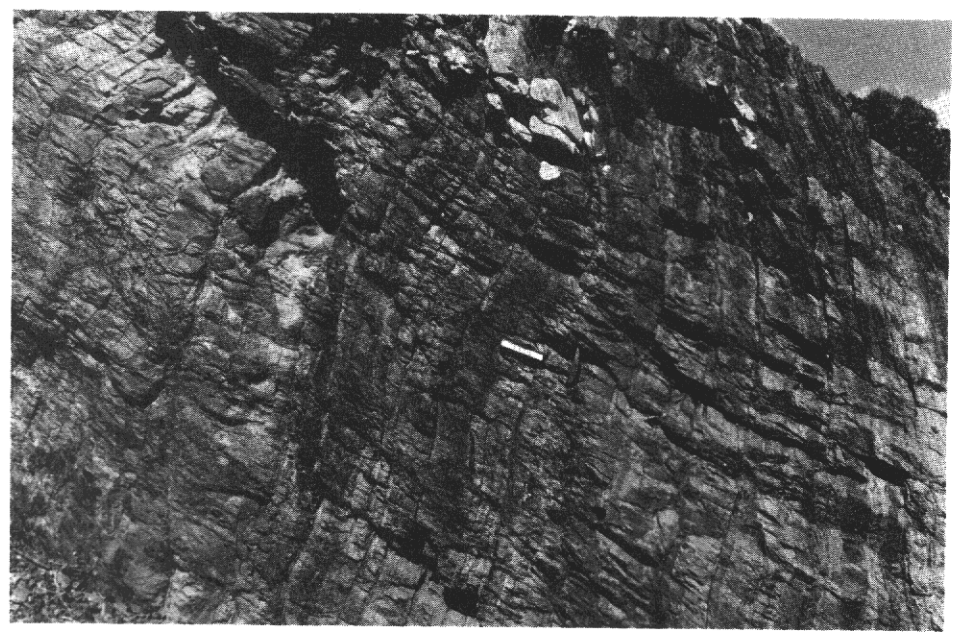

Fig. 2 Cleavage in arkosic calcarenites (with minor chert beds) at Knight Bay (locality 89-1), East End, St. Croix. Cleavage parallel to hammer handle (30 cm). Exposed face trends NNE-SSW.

FOLDED QUARTZ VEINS IN THE WEST END OF ST. CROIX

Well developed quartz veins and segregations are found at several locations in the West End of St. Croix and are particularly well displayed at localities at Hamm's Bluff (grid reference 013658) and west of Annaly Bay (grid reference 036652) . At both these localities, the quartz veins form ptygmatic folds (Fig 3) whose axial planes are parallel or sub-parallel to the cleavage (Joyce,1979, personal communication; othors own observations). This relation suggests that the veins were formed and folded in the latter stages of cleavage formation. As most of the Cretaceous sediments are calcareous, the source of the silica of the quartz veins is puzzling. It is possible that quartz rich sequences underlie the Caledonia Formation and that the silica was released during as a result of pressure solution of these hypothetical sediments. We suggest that a more likely source of silica is from cooling intermediate to felsic intrusions and therefore infer that the cleavage forming deformation in the West End is approximately synchronous with magmatic activity.

CONCLUSIONS

The features described: (1) cleavage in a porphyryitic sill, (2) cleavage in a diatreme and (3) axial planar cleavage developed in association with folded quartz veins possibly derived from cooling igneous intrusions, demonstrate that at least some igneous activity on St Croix was took place before, or was syncronous with, the tectonism which formed the slaty cleavage in the sedimentary rocks. The site west of Cottongarden Bay may be particlarly revealing. As a result of the fortuitous weathering of the outcrop close to sea level, the cleavage in the sill is easily observed. Cleavage in other intrusive rock bodies may be present but, with other weathering states, may not be so obvious. It is also possible that many intrusive bodies emplaced before tectonism may not have developed any cleavage, because they are so strong compared to the surrounding sedimentary rocks, and hence nearly all the strain (and hence slaty cleavage development) will have been accommodated by surrounding sedimentary rocks rather than by the sills. Thus, even if other intrusions predate deformation, they may only have a weak cleavage if it is detectable at all.

Our contention, therefore, is that a large part of the magmatic activity affecting St Croix preceded or was synchronous with the cleavage forming deformation. This deformation must have taken place, therefore, in the interval recorded by

Fig. 3 Folded quartz veins at Hamm's Bluff, West End, St. Croix. Bedding is subhorizontal in photograph, Regional cleavage is parallel to hammer handle, but locally is refracted into parallelism with the axial planes of folds in quartz veins.

K-Ar dates of the minor intrusions of the East End (between 71.8 and 66.1 Ma - Maastrichtian to earliest Paleocene), or later.

To resolve the question of the age of cleavage forming tectonism on St, Croix, further geochronologic studies on the intrusive rocks must include careful outcrop observations, and examination of oriented samples in thin section, to determine if tectonite cleavages, or associated syn-cleavage structures (such as folded sills with axial planar cleavages in accompanying sedimentary layers), are present.

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